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DEVELOPMENT of an AUTOMATED REAL-TIME TRACKING SYSTEM for PAVEMENT COMPACTION

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Abstract

Quality control of asphalt pavements is an important concern of highway agencies and contractors. Compaction is an important step in this process as it leads to an increase in pavement strength and durability.

While there are a number of factors that influence the in-situ pavement density, the number of passes made by the compaction device is one that is very hard to measure. One can never be certain that the desired number of passes has been made over all portions of the pavement mat. A method for automatically tracking and overlaying the number of passes over a geometric representation of the roadway would significantly enhance the quality control of this important operation.

The objective of this research is to develop a prototype system software that will map the coverage area of compaction equipment and transform this information into a computer graphics environment. This system will produce a permanent record of the number of passes made at each location on the roadway. This system will also be capable of developing a graphical representation depicting the number of passes. This will be overlaid on the roadway representation to give a complete picture as to the quality and thoroughness of the compaction operation.

Introduction

The objective of this research is to develop a prototype system that will map the coverage area of compaction equipment in real-time and transform this information into a conventional geographic information system (GIS) environment. The system produces a permanent record of the number of coverages made at each location on the asphalt mat, and will use GIS technology to develop a graphical representation depicting the number of coverages. This will be overlaid on the roadway representation to yield a complete picture of the thoroughness of the compaction operation.

The research involves instrumentation of conventional compaction equipment with a positioning device or sensor, and transmitting this information electronically to a computer for storage and manipulation in the GIS environment.

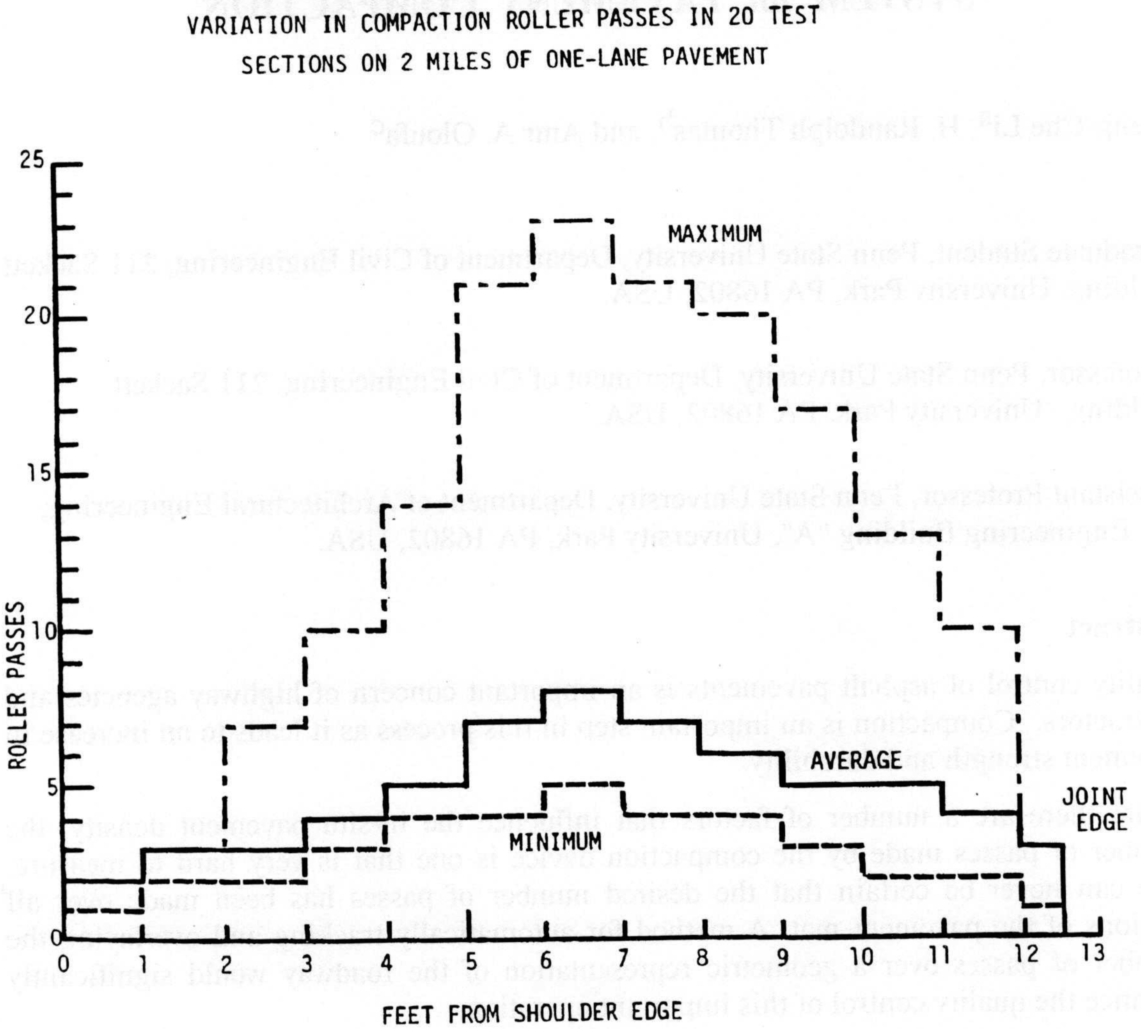

Figure 1

Figure 1 shows the variation in compaction roller passes in 20 test sections on 2 miles (3.2 km) of a one-lane paving (FHWA, 1967). The figure shows probable undercompaction at the pavement edge and probable overcompaction in the center of the pavement mat. It is apparent that if uniform density is to be achieved so that statistical type specifications are met economically, more uniform rolling must be applied (NAPA, 1981).

Pavement specifications normally call for a specific percentage of voids, or a target density after compaction. The majority of specifications penalize contractors if this void amount is not achieved. Some contracts may also penalize contractors even if the amount of voids is less than the amount prescribed in the specifications. This is because both undercompaction and overcompaction are undesirable in pavement compaction.

Undercompaction is not desirable as the target strength will not be achieved and the durability of the pavement will be reduced. Overcompaction is also undesirable as it leads to a decrease in the amount of voids that prevents the asphalt paste form expanding in hot weather leading to bleeding and cracking. Also, overcompaction can lead to further breaking of the asphalt aggregate thereby reducing the quality and durability.

Contractor normally prepare a test strip, and increase the number of passes with the compactor until the required asphalt density is achieved. This number of passes is then used on the roadway. For this reason, it is advantageous to be able to ensure that the correct number of passes has been achieved evenly over the roadway surface. Also, form the above introduction, a decrease or increase in the number of passes is not recommended as this will lead to undercompaction of overcompaction respectively.

System Components

The proposed system consists of three primary components, as shown in Figure 2. The position of the compactor will be determined with an on-board positioning device. The point position of the laser sensor will be electronically transmitted to an on-board computer notebook where the point location of the sensor will be related to the area and size features (coverage) and the orientation of the compactor. The processed data can be transmitted from the on-board computer notebook via a wireless ethernet adapter to a remote PC computer containing GIS software. Here, the data will be processed as required and stored as a GIS coverage for future reference.

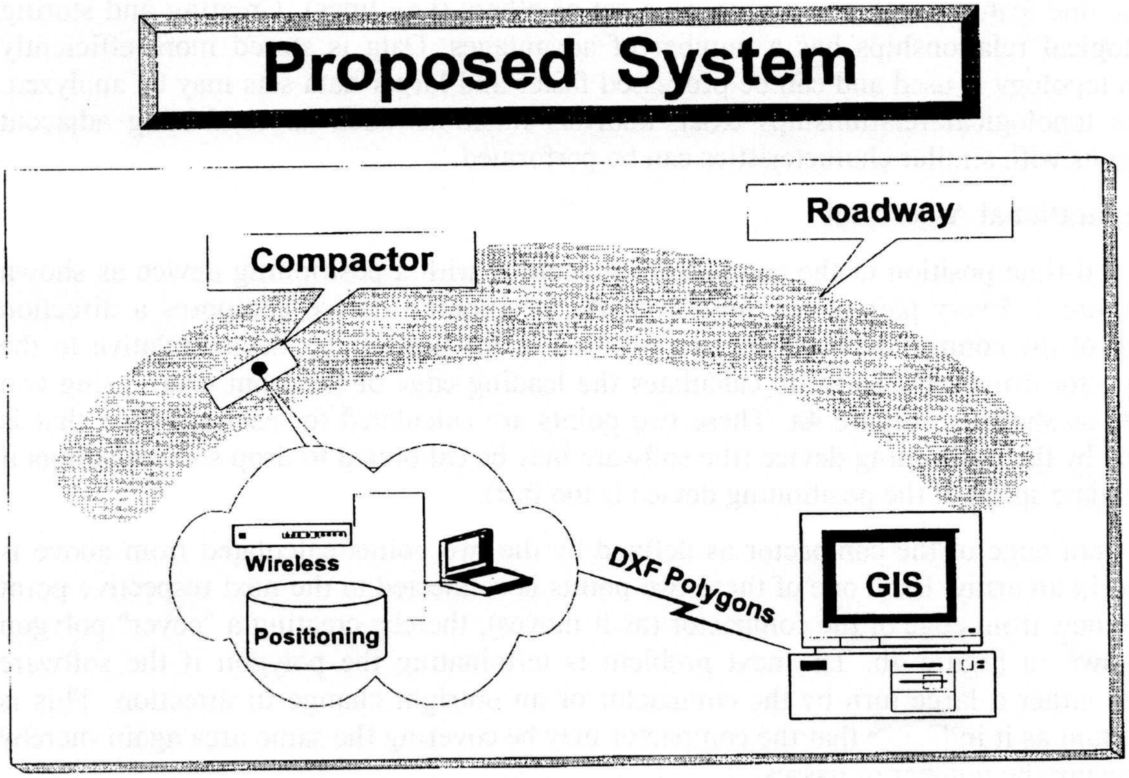

Figure 2.

The selection of GIS technology versus CAD technology was chosen since most CAD programs are not capable of complex polygon manipulation, which is needed to develop a composite description of the number of coverages (polygons) done by the compactor.

Geographic Information Systems (GIS)

GIS programs are hybrid programs that are comprised of a database engine and a geometric modeling (CAD) engine. CAD systems may also be comprised of a geometric engine linked to a database engine, however, the GIS data model also includes information related to the topology of spatial objects.

The Geographic Information System is a technology which stores and displays both spatial and non-spatial data. Spatial data is used to represent elements that have physical dimensions as one of their major attributes. For example the shape, size and location of a roadway constitutes spatial data whereas the type of its pavement is a non-spatial descriptor. Spatial data may be points, lines or polygons.

GIS programs are capable of storing data associated with different elements (based on the same geographic referencing system) in separate layers which can be superimposed spatially to support data queries and analysis.

The data model used in the GIS supports both locational and non-spatial (i.e. thematic) data structures. A digital map becomes therefore a model comprised of the combination of a topological model to represent feature locations and topology, and the relational model to represent feature attributes.

Topology defines connections between features, identifies adjacent polygons, and can define one feature, such as an area, as a set of others (i.e., lines). Creating and storing topological relationships has a number of advantages. Data is stored more efficiently when topology is used and can be processed faster and larger data sets may be analyzed. When topological relationships exist, analysis functions such as combining adjacent polygons with similar characteristics can be performed.

Computational Algorithm

The real-time position of the compactor is recorded with a positioning device as shown in Figure 3. Every pair of readings from the positioning device composes a direction vector of the compactor. Knowing the position of the positioning device relative to the compactor drums, the software calculates the leading edge of the front drum using two points as shown in Figure 4a. These two points are calculated for each position that is sensed by the positioning device (the software may be calibrated to drop some readings if the update speed of the positioning device is too fast).

The front edge of the compactor as defined by the two points calculated from above is stored in an array. Each one of these two points is connected to the next respective point of the new front edge of the compactor (as it moves), thereby creating a "cover" polygon as shown in Figure 4b. The next problem is terminating the polygon if the software senses either a large turn by the compactor or an outright change in direction. This is important as it indicates that the compactor may be covering the same area again thereby increasing the number of passes.

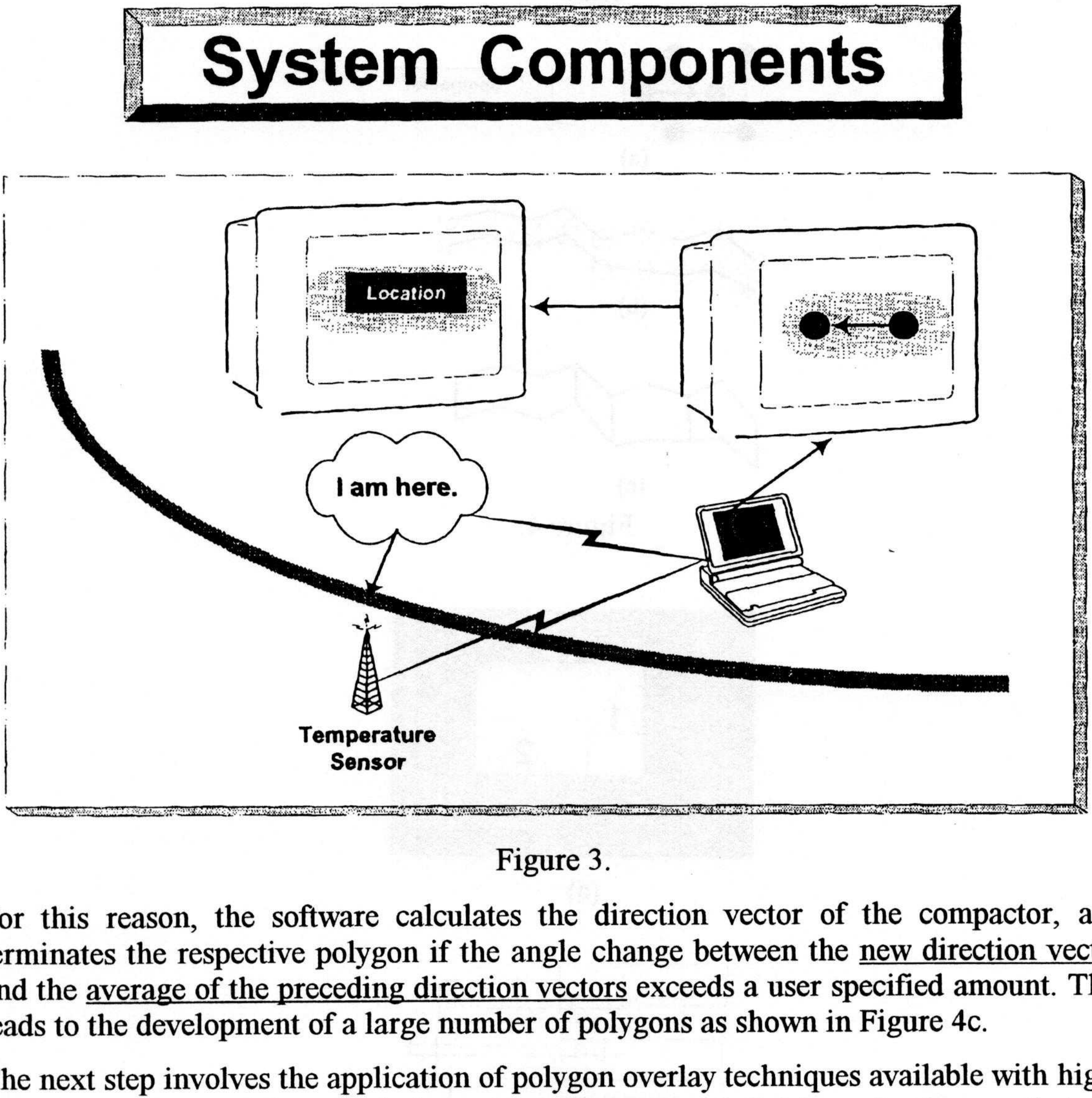

Figure 3.

For this reason, the software calculates the direction vector of the compactor, and terminates the respective polygon if the angle change between the new direction vector and the average of the preceding direction vectors exceeds a user specified amount. This leads to the development of a large number of polygons as shown in Figure 4c.

The next step involves the application of polygon overlay techniques available with high-end GIS programs. These techniques lead to a new subdivision of polygons that are linked to an array whose value at any specific polygon determines the number of passes over that area, as shown in Figure 5a.

The final output of the program will be a depiction of the roadway with the number of passes at each point as shown in Figure 5b.

Future Extensions

There exist a number of potential enhancements once the basic system is developed. For instance, other instrumentation devices and sensors can be added, such as infrared temperature sensors to measure the real-time mat temperature and accelerometers to record the vibratory frequency and amplitude of the compactor. Compactor speed can easily be calculated. The monitoring of embankments and subgrade compaction operations can easily be done. By measuring these attributes for the subgrade, pavement, and compactor equipment, it will be possible to investigate how these factors affect pavement density.

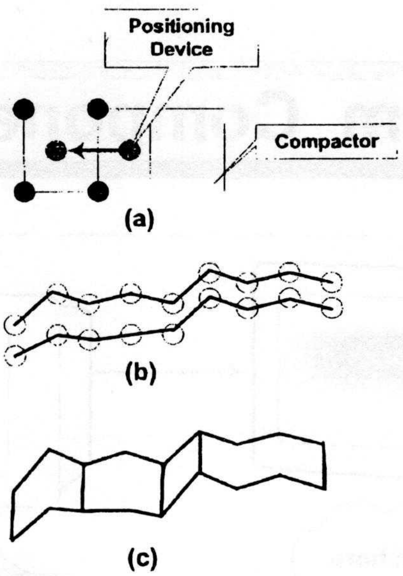

Figure 4.

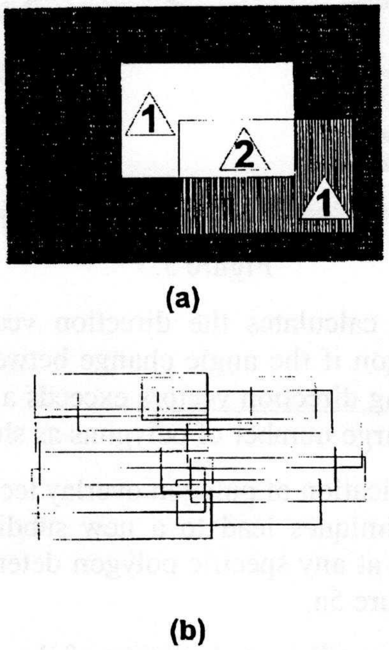

Figure 5

References

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